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THE DIATOMS OF THE QUATERNARY LACUSTRINE DEPOSITS OF THE BOLIVIAN ALTIPLANO

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RÉSUMÉ

*Les Diatomées, de chacune des principales formations lacustres du Quaternaire de l'Altiplano bolivien (*M. SERVANT, *1976) furent analysées. Elles permettent de mettre en évidence une teneur croissante des eaux en éléments dissous à mesure que l'on se rapproche des périodes récentes, la paléosalinité atteint une valeur maximum pendant l'épisode lacustre Tauca, daté de 12500 à 10500 ans B.P. On démontre que cette paléosalinité ne peut pas être expliquée par la seule dissolution des sels déposes pendant les épisodes lacustres antérieurs mais qu'elle est due aussi à un contexte uncien climatique évaporant.*

L'Holocène ancien fut étudié sur des dépôts limoneux de fond de vallée, ils contiennent une flore d'eau douce à Diatomées psychrophiles.

RESUMEN

Las Diatomeas de cada una de las principales formaciones lacustres del Cuaternario del Altiplano boliviano fueron analizadas desde el punto de vista sistemático y palenecológico.

Estas Diatomeas permiten poner en evidencia una concentración creciente de elementos disueltos, a medida que uno se aproxima a los periodos recientes, la paleosalinidad alcanza un valor marimo en el episodio lacustre Tauca (12.500-10.500 años B.P.).

Se ha demostrado que esta paleosalinidad no se puede explicar únicamente por la disolución de las sales desposttadas durante los episodios lacustres anteriores, pero que se ha debido lambien a un marco climático evaporizante.

El Holoceno antiguo fué estudiado sobre depósitos limonosos del fondo de los valles, esos depósitos contienen una abundante flora de agua dulce con Diatomeas de países fríos o montañosos.

DIATOMS IN THE ALTIPLANO QUATERNARY LACUSTRINE DEPOSITS

SUMMARY

Diatoms have been analysed in each important quaternary lacustrine formation of the Bolivian Altiplano (SERVANT, 1976). The present study shows that the dissolved element content of waters increases as the lime proceeds; palaeosalinity reaches its peak value during "Tauca" lacustrine episode, which took place between 12,500 and 10,500 years ago. It is proved that this palaeosalinity cannot be accounted for by the only dissolution of salts which have settled during earlier lacustrine episodes, but has also been due to an evaporating paleoclimatic environment.

The lower Holocene was studied on valley bottom limous deposits; they contain a fresh-water fauna including psychrophilic diatoms.

ДИАТОМЕИ ЧЕТВЕРТИЧНЫХ ОЗЕРНЫХ ОТЛОЖЕНИЙ БОЛИВИЙСКОГО АЛЬТИПЛАНО

РЕЗЮМЕ

Был произведен анализ диатомей каждой из главных четвертичных озёрных образований боливийского Альтиплано (SERVANT, 1976). Диатомеи эти позволяют выявить повышение содержания растворенных веществ в водах по мере приближения и недавним периодам ; палеосоленость достигает максимального уровня в течение озёрного апивода Таука, возрастом в 12500–10500 лет B.P. Показывается что эта палеосолёность не может объясниться одним лишь растворением солей отложившихся в предыдущие озёрные периоды, но что она также обусловлена древним климатическим испарительным контекстом.

Древний Голоцен изучался на илистых отложениях долинного дна; последние содержат пресноводную флору с холодолюбивыми диатомеями.

INTRODUCTION

The quaternary period of the Altiplano is characterized by several lacustrine expanses that have recorded variations in the region's hydrological balance.

The lacustrine deposits of the Early Pleistocene, and Middle Pleistocene remain little known since they mostly disappeared from erosion. Only the *Charaña Formation* is well-preserved; the Early/Middle Pleistocene age of the deposits is still debated. The *Vito Formation*, outlined by the Uyuni region, is related to a glacis from the end of the Middle Pleistocene (SERVANT, 1976) though its relevance remains momentarily limited since it is not known as one single outcrop.

Conversely, the lacustrine sediments from the Late Pleistocene are well-preserved, relating to the following lakes named *Ballivián* (formerly tied with the Early Quaternary), *Minchin*, and *Tauca* (SERVANT, 1976). The latter is dated to the end of the Pleistocene by ^{14}C (about 12000–10000 YBP).

The Holocene is represented by a low fluvial terrace in which the middle part, silty and sometimes peaty, is dated to about 10000–7500 YBP. The middle part contains diatom-rich flora.

The samplings taken in the lacustrine series generally focus on rather close facies in ancient shorelines. Their geographical position is given in Fig. 1. The lithology of these series is summarized by Fig 2.

CHARAÑA FORMATION

This formation lies on ignimbrite (Perez Formation) that is dated to 2.5 MYA south of Berenzuela (EVERDEN *et al.*, 1966). At least 40 m thick, it contains pebbles formed from disturbed volcanic elements, stratified calcareous diatomites, calcareous algae, and locally at the top, a calcareous crust.

The studied cross section (Fig. 2 № 1.) is located 30 km east of Charaña near the road to Abarroa.

The analyzed samples contain an abundant and varied flora (34 species were identified at level № 54). This flora is characterized by: the absence of centric diatoms, a strong proportion of *Fragilaria* to other genera, and a variety of the *Nitzschia* genus.

From bottom to top, the following evolution is observed: *Navicula* sp. (27%), *Amphora coffaeformis* (13%), *Nitzschia hungarica* (12%), *Nitzschia ovalis* (12%), then *Rhopalodia gibberula*, *Nitzschia punctata*, *Achnanthes clevei* var. *rostrata*, above *Achnanthes clevei* (44%), *Achnanthes kolbei* (13%), and a series of *Nitzschia*, *N. palea*, *N. hungarica*, *N. frustutum*, *N. punctata*, *N. navicularis*, a few *Synedra tabulate* var. *rupicola* and *Surirella striatula*.

Finally at the top, a new association develops, characterized by the predominance of *Fragilaria pinnata* (34%), *F. leptaustoron* (9%), associated to a varied flora, each species being represented by a small number of individuals. *Navicula mulica* var. *binodis*, *Epithemia zebra*, *Nitzschia denticule*, *N. capitellata*, *N. commulata*, *Amohora costata*, etc.

It is seen from the base to the top, a progressive decrease of paleosalinity of the environment, formerly abundant salts (*Amphora coffaeformis*, *Rhopalodia gibberula*), disappear little by little (*Achnanthes clevei* is a freshwater species, eutrophic in running waters), and finally the environment transforms into a freshwater environment (*Fragilaria pinnata*), certainly eutrophic. The decrease of

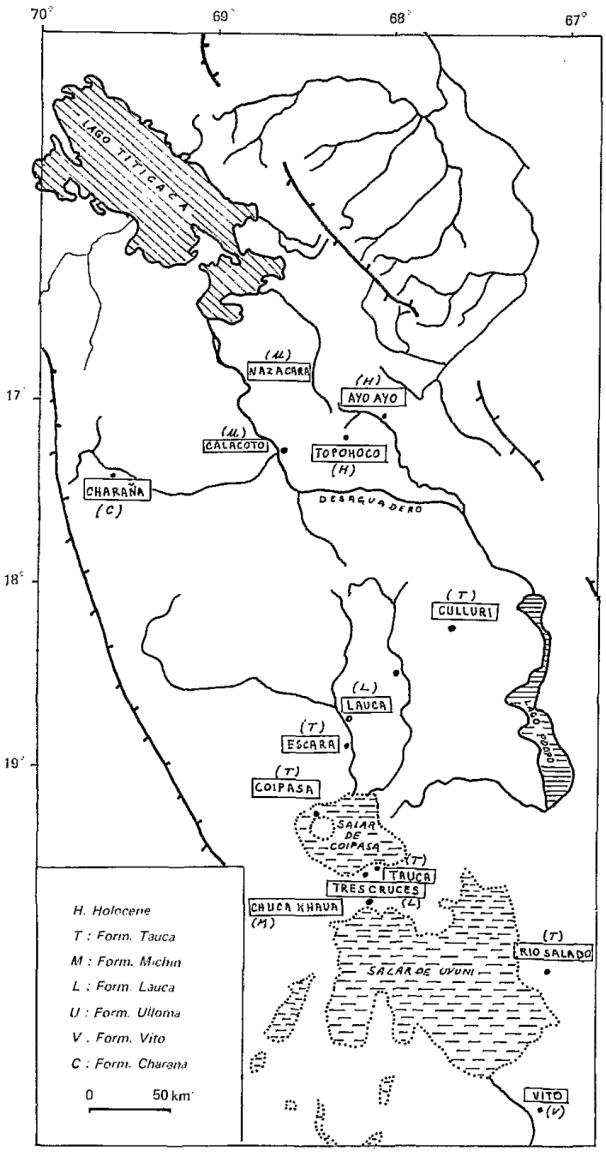


Fig. 1. — Location map.

dissolved salt content cannot be related to an elevation of the waters.

VITO FORMATION

This formation comprises windblown sands and rubble where a 2-metre-thick lacustrine layer lies between the latter. This layer may have been deposited in a sheet of water of little significant extent, perhaps simply ponds located in the floors of "quebradas".

The studied cross section is located 2 km NNW of the village Vito, on the eastern border of the Cerro Aguas de Castilla (SW of Uyuni).

The diatoms are extremely rare. The only sample that contains few (224) is located at the top of the cross section. Though the rarity of the frustules does not help define the environment. The dominant species and best preserved the is *Caloneis formosa* whose morphology is very typical, a brackish water species.

DEPOSITS OF THE BALLIVIAN EXPANSE

This lacustrine expanse has long been known around Lake Titicaca and the Desaguadero region (*Ulloma Formation*) (ALPHED, BRAVISA, 1960).

SERVANT (1976–1977) believes that another lake existed at the same time in the southern part of the Altiplano, in the Coipasa and Salars de Uyuni region. The attributed deposits make up the *Lauca Formation*.

The *Ulloma Formation* was studied in two points: on the left bank of the Desaguadero, level with the Calacoto bridge, and at Nazacara (Fig. 2 № 2–3, 8).

The *Lauca Formation* was subject of sampling, on the left bank of the Rio Lauca between the fords of the Huachacalla and Escalla (Fig. 2 № 4). Another cross section was studied on the south bank of the Coipasa, near Tres Cruces (Fig. 2 № 5).

Diatoms of the Ulloma Formation

At the bridge of the Desaguadero (Fig. 2 № 2) the studied samples may be considered as nearly pure diatoms due to the abundance of well-preserved frustules.

The essential characteristic of the flora is the abundance of *Fragilaria*. Sample № 50 consists of a tangle of—quite fragmented—thin-test *Fragilaria producta* frustules, which is also present on the opposite side. Abundant *Fragilaria construens* var. *cruciate* and var. *exigua* are found, and the presence of a centric, rare *Cyclotella pseudostelligera*, is worth noting.

The *Fragilaria* live in the shoreline of the lakes, they indicate a faintly deep environment, low in dissolved salts.

At Nazacara (Fig. 2 № 3). The low levels and poor conservation of the diatoms, has not allowed neither their counting nor the defining of their paleoenvironment. One fact stands worth noting, that is, the presence of some very rare *Stephanodiscus astrea*, this

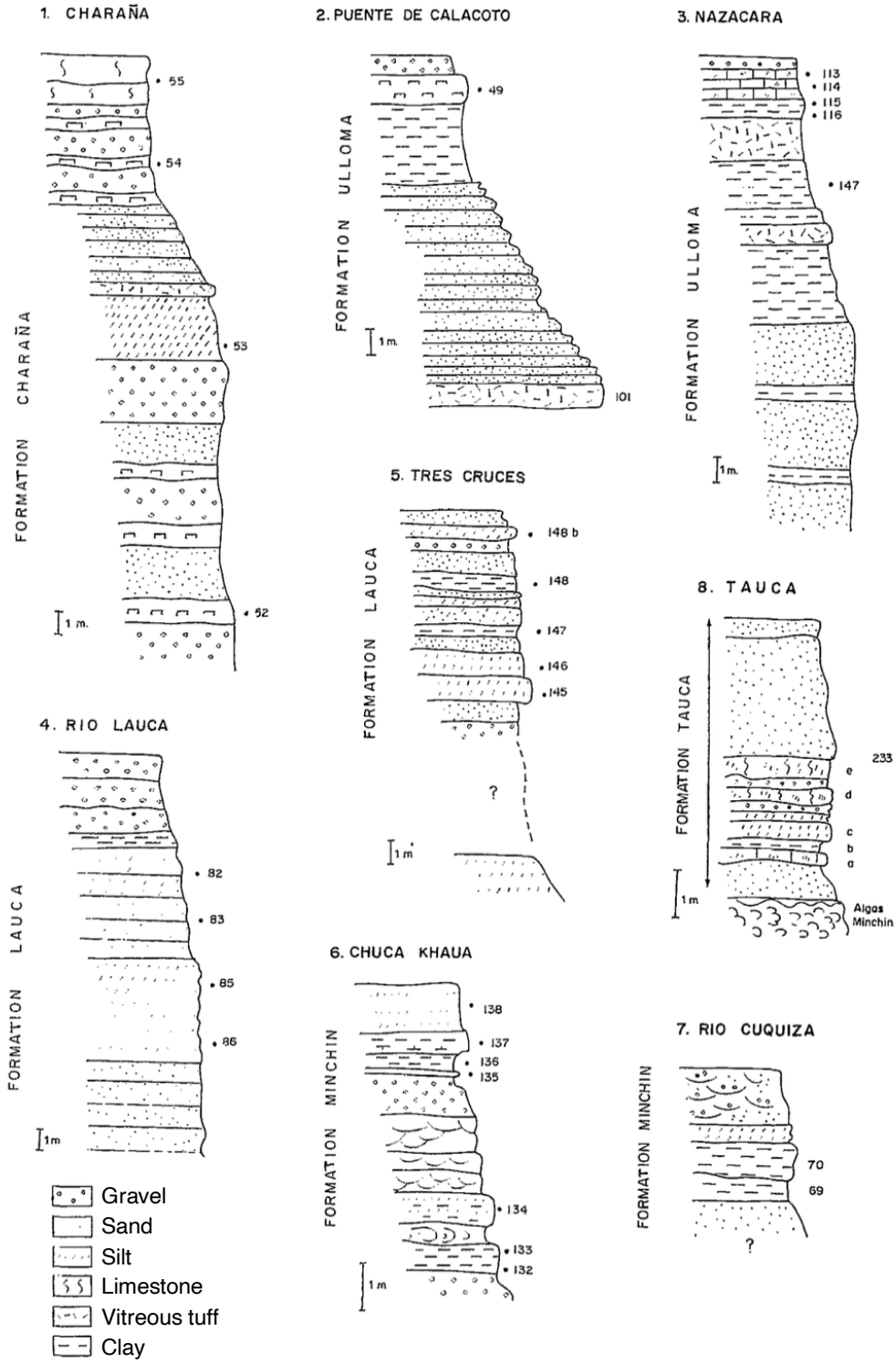

1. CHARAÑA
FORMATION CHARAÑA
55
54
53
52
1 m.
2. PUENTE DE CALACOTO
FORMATION ULLOMA
49
101
1 m.
3. NAZACARA
FORMATION ULLOMA
113
114
115
116
147
1 m.
4. RIO LAUCA
FORMATION LAUCA
82
83
85
86
1m
5. TRES CRUCES
FORMATION LAUCA
148 b
148
147
146
145
?
1 m
6. CHUCA KHAUA
FORMATION MINCHIN
138
137
136
135
134
133
132
1 m
7. RIO CUQUIZA
FORMATION MINCHIN
70
69
?
8. TAUCA
FORMATION TAUCA
233
e
d
c
b
a
1 m
Algas Minchin
Gravel
Sand
Silt
Limestone
Vitreous tuff
Clay

Fig. 2.

planktonic Coscinodiscophyceae, of eutrophic freshwater, was found only at this cross section.

Diatoms of the Lauca Formation

On the shore of the Rio Lauca (Fig. 2 № 4). Only two samples were studied, they are low in diatoms. The frustules were very broken. The presence of *Fragilaria* of very great size belonging to the species *F. leptaustoron* (85) were observed, that often exhibits ornamentation anomalies. The subdominants are: *Nitzschia punctata*, *Achnanthes lanceolata*, *Nitzschia granulate*, *Opephora marthii* (86).

The environment is difficult to define due to the miscellany of freshwater species (*Fragilaria*) and species preferring saltwater. The former are believed to be allochthonous. The location is the marginal part of the lake, subject to frequent variations of the body of water. The environnment is eutrophic; the water may contain a rather large quantity of dissolved salts.

At Tres Cruces (Fig. 2 № 5). An entire cross section was studied; the diatoms were only abundant in two levels (147 and 148). The flora is rich, and varied to a great extent (the level 147 contains for example 48 species). It is worth noting, like the other formations, the absence of Coscinodiscophyceae.

Like on the shores of the Rio Lauca, *Fragilaria* of very great size, with crude ornamentation, were found, presumed to belong to the species *F. leptaustoron*. The subdominant species being *F. pinnata*.

The freshwater species are: *Pinnularia borealis*, *Fragilaria construens*, *Navicula cari*, *Cymbella hebridica*, *Navicula mutica* var. *nivalis*, *Diploneis ovalis*, etc., and the species living in waters of greater salts concentration: *Rhopalodia gibberula*, *Surirella ovata*, *Nitzschia punctata*, *Anomoeoneis shpaerophora* var. *polygramma*.

In that case, the only parameter that is possible to define with few chances of error is the parameter of depth. The location is the coastline of a eutrophic lake. The depth of the water is weak and unstable; the water is rich in nutritional matter and in salts allowing the survival of several species.

Deposits of the Minchin expanse

Lake Minchin spans the southern part of the Altiplano, and its outline was approximately traced by Alphed, Troll (1926). The body of water reached 3.760 m of altitude. Its recent quaternary age was not yet precisely defined.

The deposits of Lake Minchin appeared in two distinct facies. They comprise constructs of calcareous algae blanketing the ancient slopes in the form of lacustrine or ancient wave-cut platforms. Beside these reefy formations, diatomaceous, sheeted sediments—calcareous to a certain extent—are deposited, which is often difficult to distinguish from the recent lacustrine deposits (Tauca). To avoid definite confusion, only the sediments located at over 3.720 m have been studied here, this altitude corresponding to the highest level of Lake Tauca, following Lake Minchin.

Corque-Huachacalla Road cross section (Fig. 2 № 7). All the studied samples belonging to Lake Minchin, are characterized by the predominance of *Cyclotella striata* (pl. I).

At Corque, the former—a planktonic Coscinodiscophyceae—represents 72% of the flora. The subdominants are: *Cocconeis placentula* var. *euglypta* (9%), *Rhopalodia gibberula* (7%) and *Diploneis smithii* var. *dilatata*, *Chaetoceros* sp.

Cycloterra striata is a mesohalobe species (3–16 g/L). *Melosira sulcata* lives in the mouths of rivers, in water in which the concentration may equate to seawater concentration, *Rhopalodia gibberula* is a species that is common in the interior salt flats.

Lake Minchin at Corque is a relatively deep lake that allows the development of a coastal flora. The middle is moderately concentrated, of mesohalobe type.

Chuca Khawa cross section (Fig. 2 № 6 and Fig. 3). This cross section was obtained from the edge of a lake, whose depth at the center of the depression, was able to be measured according to the altitude of the deposits, at 90 m roughly. The silty sediments are interspersed with frequent sandy beds of varying thickness that do not contain diatoms.

From the bottom to top of the cross section, variations of the associations are weak, the dominant species are *Cyclotella striata* and *Cocconeis placentula* and its variety *euglypta*. In the entire cross section, only 35 species have been determined.

The Coscinodiscophyceae/pennates ratio, regardless of the presence of *Cyclotella striata* is always negative (see diagram) and reaches a strong value with the thriving of *Cocconeis placentula* (level B4) which precedes the windblown sands deposits, indicating that there is—at that moment—an actual decrease of depth foretelling the dry-out occurred by the subjacent windblown sands.

The subdominant species are mesohalobe to euhalobe (3–40 g/L) : *Rhopalodia gibberula*, *Gyrosigma* sp., *Synedra tabulate*, *Rhopalodia musculus*, *Surirella*

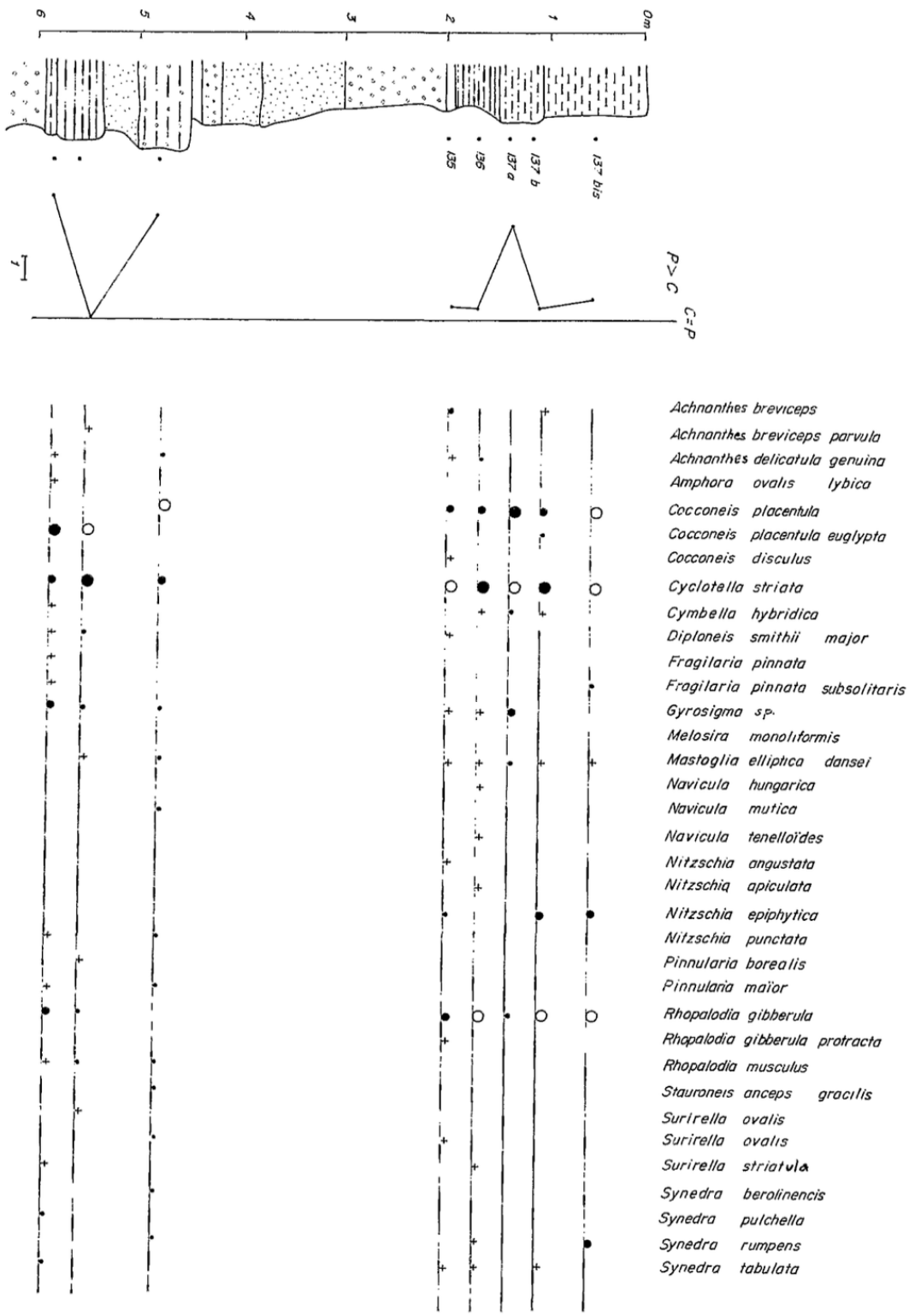
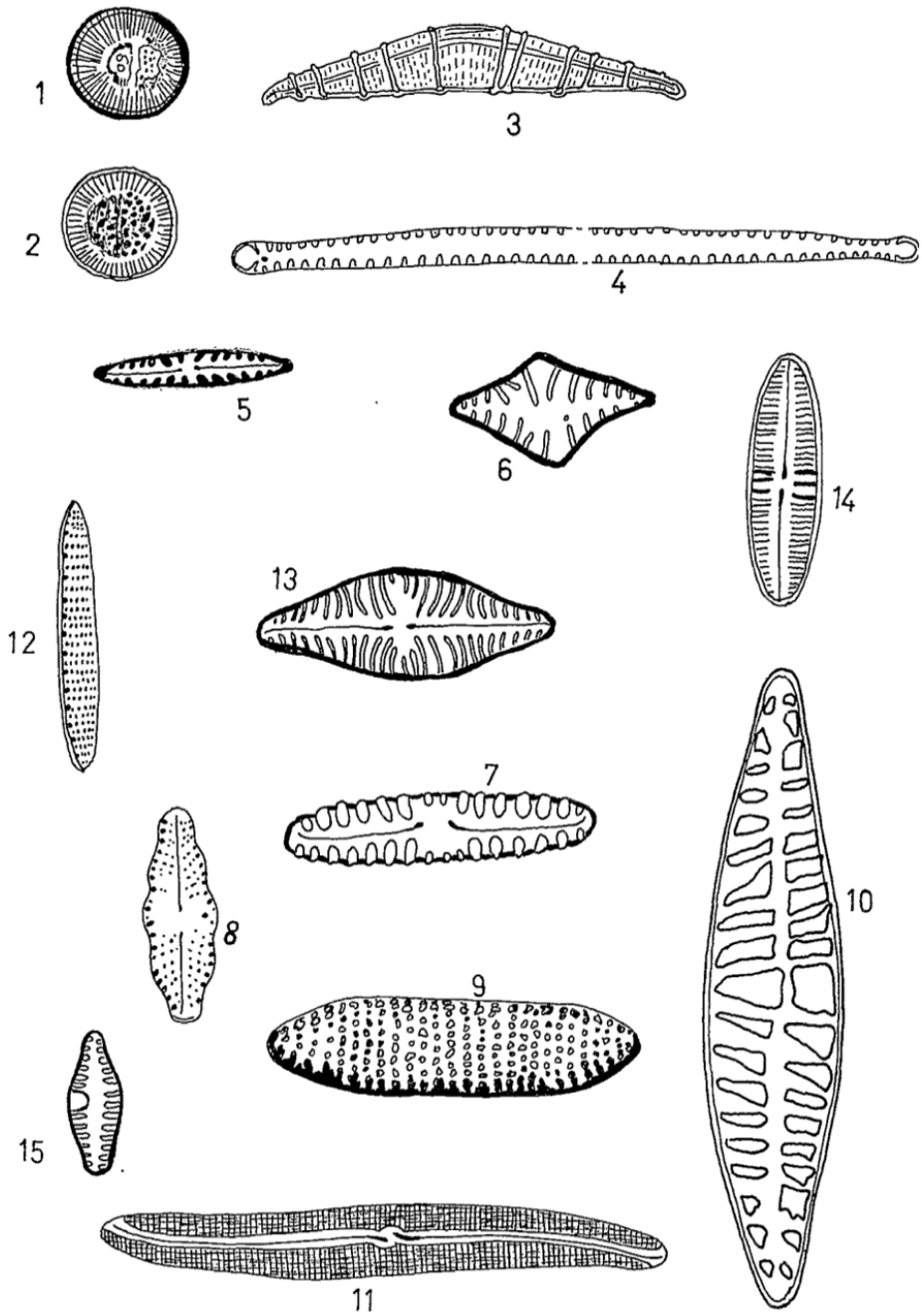


Fig. 3. — Chuca Khaua



LAKE MINCHIN. *Corque-Huachacalla Road*. 1. Cyclotella striata (Kütz) Grun (69) var bipunctata Schmidt. Diametro 10 µ. 2 . Cyclotella cf striata (Kütz) Grun (69). 3. Rhopalodia gibberula (EHR) O. Mull var producta (Grun). L. 31 µ. A. 5 µ. 4. Synedra tabulate (AG) Kütz (69). *Andamarca*. 5. Navicula hungarica Grun var. Lünebergensis Grun (17). L. 16 µ. A. 3.5 µ.

LAKE LAUCA. *Lauca*. 6. Fragilaria leptaustoron (Ehr) Hust (85). L. 20 µ. A. 11 µ. *Tres Cruces*. 7. Pinnularia borealis Ehr (147). L. 31 µ. A. 7 µ. 8. Navicula mutica Kütz var. nivalis (Ehr) Hust (147). L. 16 µ A. 6 µ. 9 Nitzschia granulata Grun (147). L. 42 µ. A. 11 µ. 10. Navicula cuspidate Kütz (147). L. 82 µ A. 18 µ. 11. Gyrosigma Spencerii (W. Smith) Cleve (147).

LAKE CHARAÑA. *Charaña*. 12. Nitzschia amphibia Grun (52). L. 35 µ. A. 5 µ. 13. Navicula salinarum Grun (52). L. 27 µ A. 9 µ. 14. Navicula plicata Donkin (52). L. 30 µ A. 9 µ.

POSTGLACIAL ALLUVIUM. *Topohoco*. 15. Achnanthes lanceolota Breb. (60). L. 10 µ. A. 4 µ.

At Andamarca (№ 17) the flora is of the same type *Cyclotella striata* (39%), present with halophilic species *Mastoglia elliptica*, *Achnanthes breviceps*, *Synedra tabulata*, *Rhopalodia gibberula*.

In summary, the flora of Lake Minchin is very distinctive, it is characterized by the intense development of *Cyclotella striata*, facultatively planktonic, mesohalobe. The studied cross sections having been found at the edge of the lake, it is normal to find some shallow-water epiphytes or bottom dwellers (*Cocconeis placentula*) associated to this species and indicating a certain richness of salts in the water (*Mastoglia*, *Rhopalodia*). The quantity of dissolved salts could reach up to 16 g/L.

Deposits of the Tauca lacustrine expanse

At its maximal extent, Lake Tauca reached an altitude of 3720 m. It covered an area of about 43000 km^2 and a maximal depth of just over 60 m. It was subdivided into three basins—almost separate—centered on Lake Poopó, the Salar de Uyuni, and the Salar de Coipasa (Fontes, Servant 1976–77). The highest lacustrine deposits were located at an altitude of around 3120 m and were dated to about 12500 and 10500 YBP.

Culluri cross section. The flora is abundant and the species that comprise it are all pennates of waters rich in dissolved salts. In order of abundance: *Achnantes breviceps* et var. *intermedia*, *Melosira sulcata* (pl. II), *Cyclotella striata*, *Chaetoceros* cf. *shutri*, *Nitzscia punctata*, *Amphora coffaeformis*, *Surirella striatula*, *Melosira monoliformis* (very rare).

Escara. The flora is also rich, but the species that make it up are different from those of Culluri. In order of abundance: *Rhopalodia musculus* (pl. II), *Cyclotella striala*, *Rhopalodia gibberula*, *Mastoglia elliptica*, *Gyrosigma kutzingii*, etc.

Rio Salado. Only two samples were studied. They both contain several well-preserved frustules. Level 166 presents a greater variety than level 165. Some 33 species were counted, in which no species were particularly predominant over the others. *Rhopalodia musculus*, *Cyclotlla striata*, *Surirella striatula*, *Nitzschia angustata*, etc.

This flora is of the same type as that of Escara, identical conditions must have existed in these two regions.

Tauca cross section (fig. 2 № 8). Eight samples taken from a cross section were subject to the study of diatoms. Associations varied little from the bottom to the top of the cross section; all samples were characterized by the predominance of *Anomoeoneis*. In detail, it was observed:

At the base: *Anomoeoneis costata* and *Navicula* sp. make up the bulk of the flora (A, B, and C), they are associated to *Nitzschia palea* and *N. amphibia*; in C, *Fragilaria construens* and *F. pinnata* increase slightly.

At D: *Anomoeoneis costata* are replaced by *Anomoeoneis sculpta* var. *genuina* (species of very large size), present with *Surirella striatula*.

At E and F: same flora as at A, B, and C.

At G: the diatoms have nearly disappeared. A few *Nitzschia amphibia* and *N. frustulum* frustules were found. It seems that there was a very short drought at G.

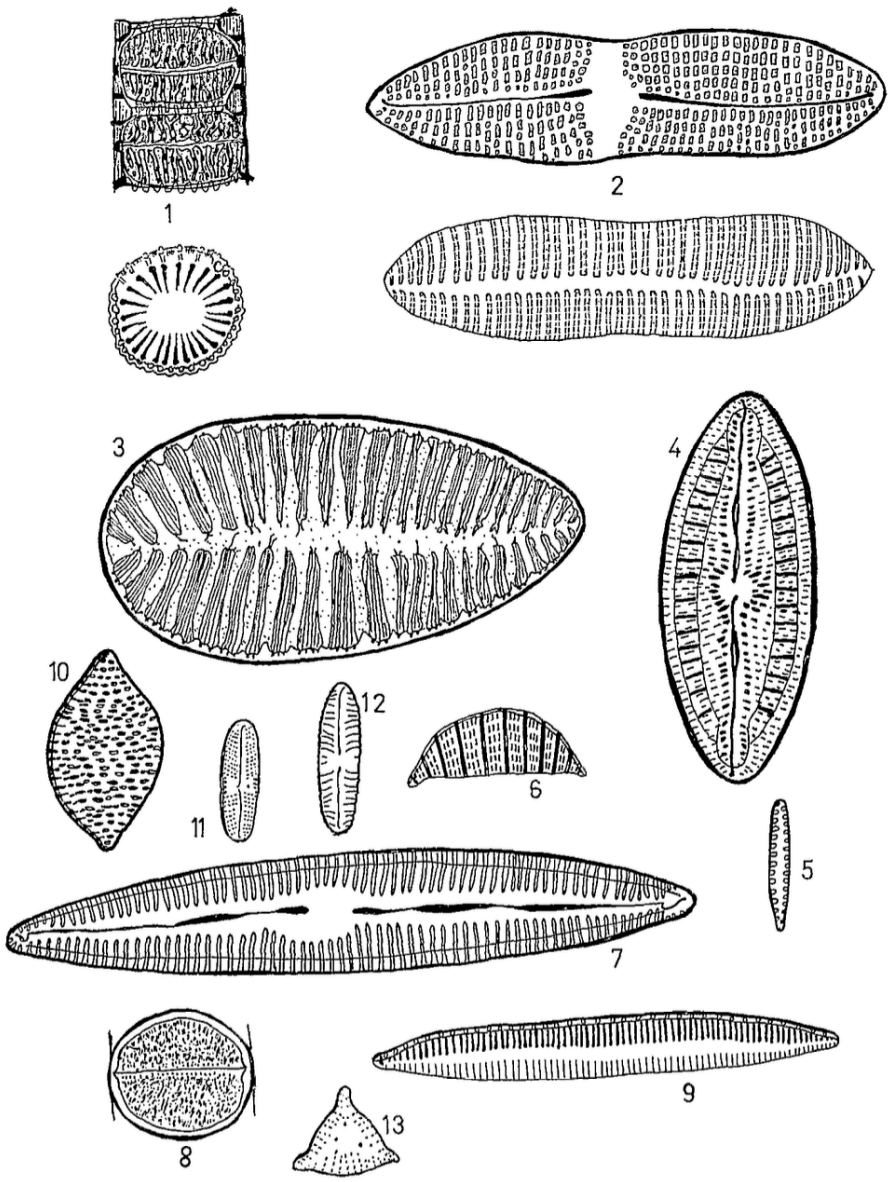
At H: the flora resembles to that at E and F, but here, the flora is more varied. Along with *Anomoeoneis sculpta* and *A. costata*, numerous *Nitzschia* (*N. stompsii*, *N. frustulum*, *N. amphibia*) appear.

Finally, at I, at the top of the cross section, the flora changes completely. It comprises 95% *Nitzschia palea*, which are often very broken, along with a few *Anomoeoneis costata* and *Nitzschia amphibia*. The sediment also contains small square crystals that are still undetermined.

The studied sediments representing the Tauca lacustrine expanse were sampled on the border of this lake. It is why the diatoms indicated a shallow environment, but Lake Tauca was a largely developed lake, deep and very rich in dissolved salts. Distribution of these salts during the Tauca lacustrine episode will now be seen.

At Culluri, the dominant species is *Achnanthes breviceps*. Hustedt (1938) identifies it as mesohalobe (3–16 g/L). But the salt's nature is unknown, the other species associated to this dominant form suggests that they are chlorides. At Escara and Rio Salado, the dominant species is *Rhopalodia musculus*, this species was described by Muller in the Fayoum, an interior salt flat, extremely concentrated particularly in sodium carbonates. Finally, at Tauca the dominant species is *Anomoeoneis costata*, then *Anomoeoneis sculpta*, var. *genuina* and finally *Nitzschia palea*. These species make up the dominant forms and are usually widespread in the salt marsh from north of Lake Chad (Iltis, 1974). These ponds are highly carbonated (up to 40 g/L) and may exhibit, for a relatively long period of time, periods of complete drying out.

During the Tauca lacustrine episode, this great, deep lake was therefore very rich in various salts, sodium chlorides



LAKE TAUCA. *Culluri*. L. l. Melosira sulcata (Ehr) Kütz (63). diametro 21µ, 2. Achnanthes breviceps AG (63). L. 76 µ. A. 23 µ. 3. Surirella striatula Turp (63). L. 63 µ. *Escara*. 4. Mastoglia elliptica Ag. (81). L. 52 µ A. 14 µ. 5. Fragilaria pinnata Ehr subsolitaris A. Cl. L. 20 µ A. 2 µ. 6. Rhopalodia musculus (Kütz) O Mull (81). L. 20 µ 1. 7 µ. 7. Caloneis formosa (Greg) Cleve (81). 8. Melosira monoliformis (O. Mull) AG. (81). Diametro 25 µ. 9. Nitzschia angustata (W. Smith) Grun. L. 52 µ A. 7 µ. *Rio Salado*. 10. Nitzschia punctata (N. Smith) Grun (166). L. 27 µ A. 15 µ. 11. Navicula mutica Kütz (166). L. 14 µ A. 5 µ. 12. Navicula mutica Kütz (166). L. 20 µ A. 5 µ. 13. Fragilaria construens (Her) Grun var. exigua (W. Smith) Schuls (166).

and sodium carbonates being its dominant dissolved elements.

HOLOCENE ALLUVIA

The hydrographic axes of the Altiplano—and particularly those of the Coro Coro "serrania"—present a low, gravelly terrace with 2–4 m of locally interspersed peaty silt inserted between. These outliers are very rich in diatoms.

Ayo Ayo deposits. The flora consists solely of pennates that provide initial indication of depth. It is a swamp or a floodplain, the phytoliths found abundantly in these deposits point to the same direction that the diatoms indicate. According to the position of the deposits, it certainly was a film of water, well oxygenated, of *Nitzschia denticule* and *Cymbella microcephala*, weakly carbonated of up to 3 g/L (the preferential salt being calcium carbonate) and may be quite cool—as a matter of fact, a considerably great quantity and variety of *Cymbella* with symmetrical test attributed to *C. alpina*, *C. norvegica*, *C. cesatii* were encountered, which suggests a low water temperature.

Topohoco deposits. Like at Ayo Ayo, the diatoms are abundant, and a great quantity of species were able to be determined, but all of them, like at Ayo Ayo, are pennates that are epiphytic, benthic, or facultative planktonic. By order of abundance: *Fragilaria construens* var. *exigua*, *F. construens*, *F. brevistriata*, *F. brevistriata* var. *undulata*, *Cymbella norvegica*, *Cymbella cistula*, *Achnanthes lanceolata*, *Achnanthes dispar*.

These diatoms have found an environment particularly favorable to their development, which may be characterized as shallow, oligotrophic, well-oxygenated, and cool. The main psychrophilic species are: *Cymbella aequalis*, *C. norvegica*, *C. gracilis*, *C. hebridica*.

CONCLUSION

Most Pleistocene lakes of the Bolivian Altiplano contain flora characteristic of environments very rich in dissolved elements, with dominance depending on regions of sodium chlorides or sulphates, or sodium carbonates.

The lowest paleosalinity values are located at Lake Ballivian: the Ulloma formation was deposited in a deltaic region of which its paleosalinity may not have been characteristic of the lake as a whole, the studied sediments as a matter of fact contain only freshwater species. However, the Lauca formation contains saltwater species, associated with a high proportion of freshwater species of the same type as those of the Ulloma formation.

Paleosalinity becomes high at Minchin (mesohalobe lake, 3–13 g/L) and reaches a greater value at Lake Tauca, where waters would have been moderately to highly carbonated (up to 40 g/L).

The Holocene alluvial deposits contain an epiphytic, freshwater flora, with several species preferentially living in mountainous and cool regions.

It is likely that each of these lacustrine expanses have redissolved some of its previously deposited salts. It can be calculated, for example, that the partial redissolution of Lake Minchin was able to immediately produce a salinity of 8–10 g/L to the waters of Lake Tauca. *This process may partially explain the increasing paleosalinity of the Quarternary sheets of water over time to recent periods.*

However, the high amount of dissolved elements probably cannot be explained without strong evaporation, which implies a relatively dry climatic context, with concentrated rains on a few months of the year. It is still difficult to determine the exact origin of the waters of these lakes. The latter (Tauca) may have been due partially to the melting of glaciers. The additional water thus provided, would have been enough to introduce a positive factor in the global hydrological balance of the Altiplano. More recent stratigraphic studies would be necessary to determine if this interpretation is applicable to prior lakes.

The silty alluvions of the lower Holocene contain freshwater flora, which is natural given that the waters have not been subjected to a long evolution by evaporation. The presence of psychrophilic diatoms may indicate the sustaining of a relatively cool climate.

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BIBLIOGRAPHY

AHLFED (F.), BRANISA (L.), 1960. — Geologia de Bolivia. *Inst. Bol. Petr.* Don Bosco, ed., La Paz, 245 p.

BORRELLO (A.), 1966. — Paleontografia bonacrense. Fasc. 1. Protista. Provincia de Buenos Aires Gobernaciòn. Comisiòn de Investigaciòn cientifica. La Piata.

EVERDEN (f.), KRIZ (S.), CHERRONI (C.). 1966. — Correlaciones de las formaciones terciarias de la cuenca altiplanica a base de edades absolutas determinidas por metodo potasis-argon. *Hoja Informitiva*, № 1, *Serv.. Geol. de Bol.*

FRENGUELLI (I.), 1929. — Diatomee fossili delle conche saline del desserto cileno-boliviano. *Boll. Soc. Geol. Italiana*, vol. 47, № 10–14:185–236.

FRENGUELLI (J.), 1939. — Diatomeas del Lago Titicaca. Notas del Museo de la Plata *Botanica*, vol. 24, № IV :175–196, 1 pl.

FRENGUELLI (J.), 1939. — Vestigios de una fase lacustre reciente en la cuenca de la Salina chica en Peninsula Valdez (chubut). *GAEA An. Soc. Arg. Est. Geográficos*, vol. VII:65–71, 1 pl.

MANGUIN (E.), 1964. — Contribution à la connaissance des Diatomées des Andes du Pérou. *Mem. Mus. nat. Hist. nat.*, ns, ser. B., But., vol. 12, № 2:1–98, 25 pl.

MÜLLER (O.), 1899. — Bacillariaceen aus der Natronthälern von El Kab (Ober Aegypten). *Hedwigia*, vol. 38:274–321.

SERVANT (M.), 1976. — El Cuaternario del Altiplano de Bolivia. Extensiones lacustres y morfogenesis. *In Primer Congresso Nacional de Geologia*, Potosi, Bolivia (in press).

SERVANT (M.), 1977. — Le cadre stratigraphique du Plio-Quaternaire de l'Altiplano des Andes tropicales en Bolivie. *In Recherches françaises sur le Quatrnaire. INQUA*, 1977, Suppl. Bull. AFEQ, 1977-1, № 50:323–327.

WIDMER, (C.), Kittel (T.), Richerson (P. J.), 1973. — A survey of the biological limnology of Lake Titicaca. *Verh. Intern. Verein. Limnol.*, vol 19:1504–1510